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An introduction to European willows

Alexander Robertson

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AN INTRODUCTION TO EUROPEAN WILLOWS

by Alexander Robertson

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ABSTRACT

As a short rotation agroforestry crop, willow coppice and osier production dates back to early Greek and Roman civilizations. Within the last decade willows have again become attractive as a cheap, fast-growing energy source. New research and development programs on short-rotation energy plantations are underway in Sweden, Eire, Britain, Finland, New Zealand and, more recently, Canada and U.S.A. This report provides a basic introduction to European willows in general and the potential of commercial species in particular. Historical notes include selected examples of early uses and mythology that influenced contemporary perception and cultivation of willows.

RÉSUMÉ

La culture agroforestière à rotation courte de l'osier et des saules en taillis remonte aux débuts des civilisations grecque et romaine. Au cours de la dernière décennie, les saules ont connu un regain de faveur en tant que source modique et à croissance rapide d'énergie. De nouveaux programmes de recherche et de dévelopement sur les plantations à rotation courte sont en cours en Suède, en Irlande, en Grande-Bretagne, en Finlande, en Nouvelle-Zélande et, depuis peu, au Canada et aux États-Unis. Le présent rapport constitue une introduction fondamentale aux saules européens en général et aux possibilités de certaines espèces commercialisables. Des notes historiques donnent des exemples des premières utilisations et des mythes qui ont influé sur la perception et la culture contemporaines du saule.

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HISTORICAL NOTES

Since the knowledge of willows is of great antiquity, it is with the ancient Greeks and Romans we shall begin, for among these people numerous written records remain.

The growth habit, ecology, cultivation and utilization of willows was well-understood by Theophrastus, Ovid, Herodotus, Pliny and Dioscorides. Virgil was also quite familiar with willow, e.g. Damoetas complains that:

> "Galatea, saucy girl, pelts me with apples and then runs off to the willows".
>
> ECLOGUE III

and of foraging bees:

> "Far and wide they feed on arbutus, pale-green willows, on cassia and ruddy crocus ..."
>
> GEORGICS IV

Theophrastus of Eresos (370-285 B.C.) discussed many aspects of willows throughout his Enquiry into plants including habitats, wood quality, coppicing and a variety of uses. Willows, according to Theophrastus are lovers of wet places and marshes. But he also notes certain amphibious traits of willows growing in mountains and plains. To Theophrastus they appeared to possess no fruits and quite adequately reproduced themselves from roots, were tolerant to flooding and frequent coppicing. "Even willows grow old and when they are cut, no matter at what height, they shoot up again." He described the wood as cold, tough, light and resilient - qualities which made it useful for a variety of purposes, especially shields. Such were the diverse virtues of willow that he suggested introducing it for plant husbandry. Theophrastus noted there were many different kinds of willows; three of the best known being black willow (Salix fragilis), white willow (S. alba) and an intermediate type (S. amplexicaulis). Black willow was distinguished by its red and black bark and was the most serviceable for basketry. White willow was distinguished by its white foliage but was less desirable for basketry because of its brittleness. The intermediate willow had characteristics of both but did not grow as well.

Because of its affinity to water the willow figures prominently in poetical writings down through the ages. Herodotus notes the curious use of willow divining rods by the Scythians (a practice which still survives in many countries). Ovid, a contemporary of Virgil alludes to willow habitats as:

"A hollow vale where watery torrents gush.
Sinks in the plain the osier and the rush.
The marshy sedge and bending willow, nod
Their trailing foliage o'er the oozy sod.

MET. LIB. VII

Likewise, Shakespeare relating willows to the death of Ophilia:

"There is a willow grows ascaunt the brook,
That shows his hoary leaves in the glassy stream,
There with fantastic garlands did she make,
Of crowflowers, nettles, daisies and long purples,
There on the pendent bows her coronet weeds,
Clambering to hang an envious silver broke;
When down in her weedy trophies and herself,
Fell in the weeping brook."

The classical picturesque scene of weeping willows, growing by a river or lake, so common around the world in parks and gardens, tends to reinforce the popular view that willows are primarily aquatic. Many would be surprised to learn that even the sacred weeping willow can thrive on relatively dry sites.

Ironically, the origin of the weeping willow is still one of the great enigmas of botany. When Linnaeus, the famous Swedish botanist, named it he thought it was native to Babylonia partly on account of a Biblical reference to willows:

"By the rivers of Babylon there we sat down,
yea we wept when we remember Zion.
We hanged our harps upon the willows
in the midst thereof."

Psalms 137:1-2

Ancient Babylon was located on the lower Euphrates, south of Baghdad. Contemporary botanists believe that the Biblical 'willow' was actually a poplar (Populus euphratica). Their reasoning being that in Biblical times the 'gharab' meant poplars and, when the Bible was translated into vernacular during the Reformation, it came to signify willows.

But then, out of Psalm 137 there evolved an old Arabian storyteller's version of King David's repentance after he married Bathsheba that was better known in Linnaeus' time than it is now. The gist of the story goes that two angels visited David in his chambers and made him convict himself of his adulterous crime; henceforth, he wept and trembled in judgement of the Lord for forty days and nights. His tears of repentance were so great as to form two streams which flowed out of his chambers into the garden. Where the two streams soaked into the garden soil there sprung up two trees, the weeping willow and the frankincense tree; the first weeps and mourns, the second continually sheds tears of repentance in memory of David. Many centuries later, when Alexander the Great journeyed up the Euphrates by boat he passed under a willow tree whereupon one of its branches caught the crown from his head. The event was seen as a bad omen by the Babylonian diviners and caused them to predict his early death. It is from these Arabian stories that weeping willow has come to be associated with so much poetical gloom and doom of lost love and dark forebodings.

It was well-known then that most European willows grow naturally in cool, moist soils; the exceptions being S. acutifolia and S. daphnoides which grow in dry soils of mountains and continental plains. Willows are seldom, if ever, found on wet sphagnaceous bogs, although other types of peatlands accommodate some willow species. These will be discussed later; suffice to note here that, in nature, some species characteristic of moist alluvial sites have long been cultivated on dry sites.

In northern Europe, specifically Britain and Scandinavia, willows were extremely important long before recorded history. Apart from the extensive use of willows for fuel, food and weapons, Druid legends have it that huge wickerworks were filled with criminals and set afire on great occasions. In the first century (A.D.) Martial, a Roman poet, refers to a thriving export basket trade between Britain and Rome:

"From Britains painted sons I came,
And basket is my barbarous name;
But now I am so modish grown,
That Rome would claim me for her own."

Basketry was a major industry of many areas in Britain until recently. It is now rather limited to the fen districts of southern England. It had always been a part of agriculture, although agroforestry may not be too strong a term for the basket industry as it was practiced in earlier times. In 1327, for example, the parishes of Wells and

Glastonbury agreed to apportion the pasture rights. Under this agreement tenant farmers were granted the right to pasture animals and harvest wood (mainly willow coppice). A complicated structure administered by the monasteries had grown to control these operations (Williams 1970).

Still earlier references to managing coppice on the fens, dating from 1189 A.D., are contained in the Statutes of Merton. In the same period, Henry VII granted the right to gather firewood (husbote and keybote) which went with the pasture rights. According to these ancient monastic and Royal decrees, husbote and keybote were derived almost exclusively from willows.[1] For example:

> "In the southern levels, droves and rhynes are lined by rows of short-trunked willow trees, heavy and bushy with trailing foliage in the spring and summer, but later when cut and pollarded, looking naked and gaunt, like so many giant, bulbous-topped, knockberries stuck in the ground. The rhynes are full of withy shoots, rolling in water, ready to be taken away to one of the multitude of drying sheds, with characteristic tall chimneys which dot the moors."

Although at a much later date, Gerard (1633) provided an illustration of a pollarded willow (Figure 1). Today, coppicing willows for basketry (and fuelwood as a by product) is still a thriving industry in localized areas of Somerset, England as well as in other areas in Europe, particularly along the Danube.

While all this may seem peripheral to our times, it is well to note that most of the willow clones being used in basketry today and those being contemplated for energy plantations, were selected from spontaneous hybrids in these far off times, the specific details of their precise origin having been lost in antiquity. Furthermore, the management practice for cultivating rods for basketry is identical with the principle proposed for short rotation energy plantations. It differs only in the harvesting and utilization aspects.

BIOGEOGRAPHY OF EUROPEAN WILLOWS

Numerous vegetation maps of Europe have been produced (of northern Europe in particular), and Ahti et al. (1968) have given an excellent review. The multiplicity of such maps has resulted in considerably unstable and confusing terminology, which is an obvious trait in contemporary geobotany (Hämet-Ahti 1981).

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[1] Cartulary of St. Marks, Bristol, ed. Ross-Bristol Record Society XXI, No. 440; Cal. Inquist. Post. Mert. Henry VII, III, 310-311; 'Pedes Finium', No's 6(1330-1) and 17(1342-3), S.R.S. XII; and 'Pedes Finium', No. 144 S.R.S.

3 *Salix Caprea rotundi folia.*
The Goat round leafed Willow.

4 *Salix Caprea latifolia.*
The Goat broad leafed Sallow.

5 *Salix Roſea Anglica.*
The Engliſh Roſe Willow.

Roſe, of a greeniſh white colour, which doe not only make a gallant ſhew, but alſo yeeld a moſt cooling aire in the heat of Sommer, being ſet vp in houſes, for the decking of the ſame.

6 The low or baſe Willow groweth but low, & leaneth weakly vpon the ground, hauing many ſmall and narrow leaues, ſet vpon limber and pliant branches, of a darke or blackiſh greene colour: amongſt which come forth long ſlender ſtems full of moſſie floures, which turne into a light downie ſubſtance that flieth away with the winde.

7 The dwarfe Willow hath very ſmall and ſlender branches, ſeldome times aboue a foot, but neuer a cubit high, couered with a duskiſh barke, with very little and narrow leaues, of a greene colour aboue, and on the vpper ſide, but vnderneath of a hory or ouerworne greeniſh colour, in bigneſſe and faſhion of the leaues of garden Flax: among which come forth little duskiſh floures, which doe turne into downe that is carried away with the winde: the root is ſmall and threddy, of the bigneſſe of a finger, and of a blackiſh colour.

8 There is another kinde of willow like to the former, and differeth from it in that

Figure 1. Extract from Gerard's Herbal (1633) showing a pollarded willow.

For the purpose of discussing willows, two types of maps could be produced: one showing boreal and mixed forest and wild grassland within areas of human interference; the other, a theoretical construct of climate, geology and climax vegetation, ignoring all effects of natural arresting factors and human interference; i.e., the potential natural vegetation. For much of Europe neither seems to provide a suitable alternative. Even if we accept geomorphic factors in remote regions as beyond human influence we may have to account for the effects of acid rain and ozone which cause particular problems in Europe.

The influence of human activity in lowland areas benefits the distribution of a number of willow species through the creation of subsere (subclimax) vegetation. The fens of east Anglia are an example of a flat plain, near sea level, on which carr vegetation of Alnus and Salix are dominant in 'undisturbed' sites (Eyre 1968; Tansley 1965). In these fens the hydrological conditions arrested the prisere at a fairly early stage, giving rise to the subsere (semipermanent) carr vegetation. However, when the fens are drained, the seral development will resume towards another climax. In such cases, a transition can be observed from Salix species that prefer wet sites to those that prefer drier sites; or, in some cases, the elimination of Salix and Alnus altogether.

In the mixedwood and coniferous forest regions of central and eastern Europe plagioseres, where clearcutting of forests has resulted in a change from forests to shrubs and herbs, willows are common. Many of the plagiosere communities have been converted to grasslands for animal husbandry. But when these grasslands are abandoned they usually revert to a forest vegetation with willows, especially apophytic species, dominating the shrub layer with alders in the first seral transition stage. This phenomenon can be observed in Finland and Sweden where peatlands with coniferous and birch forests were cleared and drained during the 1940's and 1950's and later abandoned in the early 1970's. Here, natural regeneration of shrubs and trees occurs on the drier sites along the edge of drains. The regeneration contains a substantial complement of Salix species in addition to Betula alba, Picea abies and Pinus sylvestris, while the wetter sites, with lush grassy meadows, are sparsely colonized by Salix.

In the mountain and arctic tundra chaemophytic willows are well represented, especially on the humid, fog-shrouded slopes. On flat tundra where snow melt is slow, concentric or polygonal patterns of vegetation may be dominated by Salix herbacea (Daubenmire 1978). Chmelar (1977) gives an extensive biogeographical treatment of low-growing willows suitable for planting in rock gardens, including the natural habitats of each species.

Inclusion of a detailed vegetation may of Europe is declined principally because one which would be related to the distribution of willows would require extensive study and also for other reasons outlined by Ahti et al. (1968) and Hämet-Ahti (1981). These include:

- the lack of appropriate vegetation descriptions making comparison and mapping impossible;

- that no single climatic factor is useful because the relationship between plants, climate and geomorphology is very complex and variable locally and regionally.

Since phytogeographic boundaries, including bioclimatic divisions, must be based on plant communities of the regional vegetation (Kalela 1960) it would be especially difficult to prepare a map that includes ruderal species of willow as a general framework because they are often short-term components in dynamic (seral) vegetation structures. For a general vegetation map the reader is referred to the many versions contained in the standard atlases.

According to Jalas and Suominen (1978) there are 70 species of Salix native to Europe, but they are uncertain of the status of several of them. Goode (1974) notes that many species of the genus Salix occur as two or more well-marked varieties and a considerable number of hybrids. Skvørtsov (1968), on the other hand, is of the opinion that although interspecific hybridization and introgression are responsible for wide variations, they are by no means as common as reported in literature. On this point he agrees with Buser (1887) that 80-90% of willow specimens in herbaria named as hybrids are simply variants of species, bearing in mind that human perception is more apt to dwell on gross differences than subtle constant traits. No doubt the profusion of apparent hybrids has intimidated many a forester and ecologist.

In the majority of cases willows tend to frequent the periphery of vegetation units or hemerophilic sites such as hedgerows, roadbanks and 'waste' ground. Hence, even though they occupy an insignificant place in the native flora, ecologists tend to restrict them to the anthropogenic vegetation and overlook their natural ecological niche. Nevertheless, there are many biomes where willows are indeed a dominant component of the natural vegetation. In the Danube Valley and its tributaries Salix alba forms extensive stands occupying over 20 000 ha in Yugoslavia, and 80 000 ha in Romania (Anon. 1979). In other regions of Europe willows are a major constituent on peatlands, mountains and arctic tundra. While not every species of European Salix will be discussed, a sufficient selection will be presented which will give a general account of the ecological amplitude and economic importance of willows in Europe.

For convenience the willows have been grouped into broad topographic regions and easily understood biomes, such as tundra, lowland, boreal, Mediterranean, etc.

Arctoalpine species of Scandinavia and/or Arctic tundra and Urals.

S. polaris Wahl.
S. myrsinites L.
S. pulchra Cham.
S. reptans Rupr.
S. recurvigemmis Skvørtsov
S. nummularia N.J. Andersson
S. arctica Pallas
S. glauca L.
S. lanata L.
S. arbuscula L.

Arctoalpine species of northern and central Europe.

S. reticulata L.
S. foetida Schleich
S. hastata L.
S. daphnoides Vill.
S. herbaceae L.
S. waldsteiniana Willd.
S. lapponum L.

Alpine species of central and southern Europe.

S. retusa L.
S. serpillifolia Scop.
S. alpina Scop.
S. pyrenaica Gouan
S. bicolor Willd.
S. mielichhoferi Sauter
S. crataegifolia Bertol.
S. appendiculata Vill.
S. helvetica Vill.
S. eleagnos Scop.
S. kitaibeliana Willd.
S. breviserrata B. Flod.
S. glaucosericula B. Flod.
S. hegetschweileri Heer.
S. apennina Skvørtsov
S. glabra Scop.
S. siliciaca Willd.
S. laggeri Wimm.
S. cassia Vill.

Alpine-boreal species.

S. phylicifolia L.
S. starkeana Willd.
S. myrtilloides L.
S. repens
S. nupsinifolia Salisb.
S. xerophila B. Flod.
S. rosmarinifolia L.
S. pyrifolia Ledeb.

Mediterranean species.

S. pedicellata Desf.
S. aegyptiaca L.
S. amplexicaulis Bory
S. tarraconensis Pau

Lowland-subalpine species

- throughout most of Europe

S. pentandra L.
S. triandra L.
S. cinerea L.
S. aurita L.
S. caprea L.

- western and central Europe, excluding most of N. British Isles and N. Scandinavia.

S. viminalis L.
S. alba L.
S. fragilis L.
S. purpurea L.

- Eastern Europe

S. rosmarinifolia L.
S. acutifolia Willd.

- Western Europe

S. atrocinerea Brot.
S. salvifolia Brot.
S. repens L.

Arctoalpine Species

Arctoalpine willows constitute by far the largest number of species.

In the lower alpine zones of mountains in northern Europe the grey willows, particularly Salix glauca, S. lapponum and the slightly calcicolous S. lanata, are the most important. Also present with these is S. phylicifolia. This group dominates the shrub layer of peatlands, alpine meadows and moist heath. S. glauca prefers the richer sites while S. phylicifolia and S. lapponum occupy the bogs and S. lanata the lower alpine fens (Rune 1965; Persson 1965). Holmen (1965) notes that in the low alpine zone S. lanata, S. lapponum and S. reticulata favor south slopes, whereas S. herbacea and S. hastata favor the moister

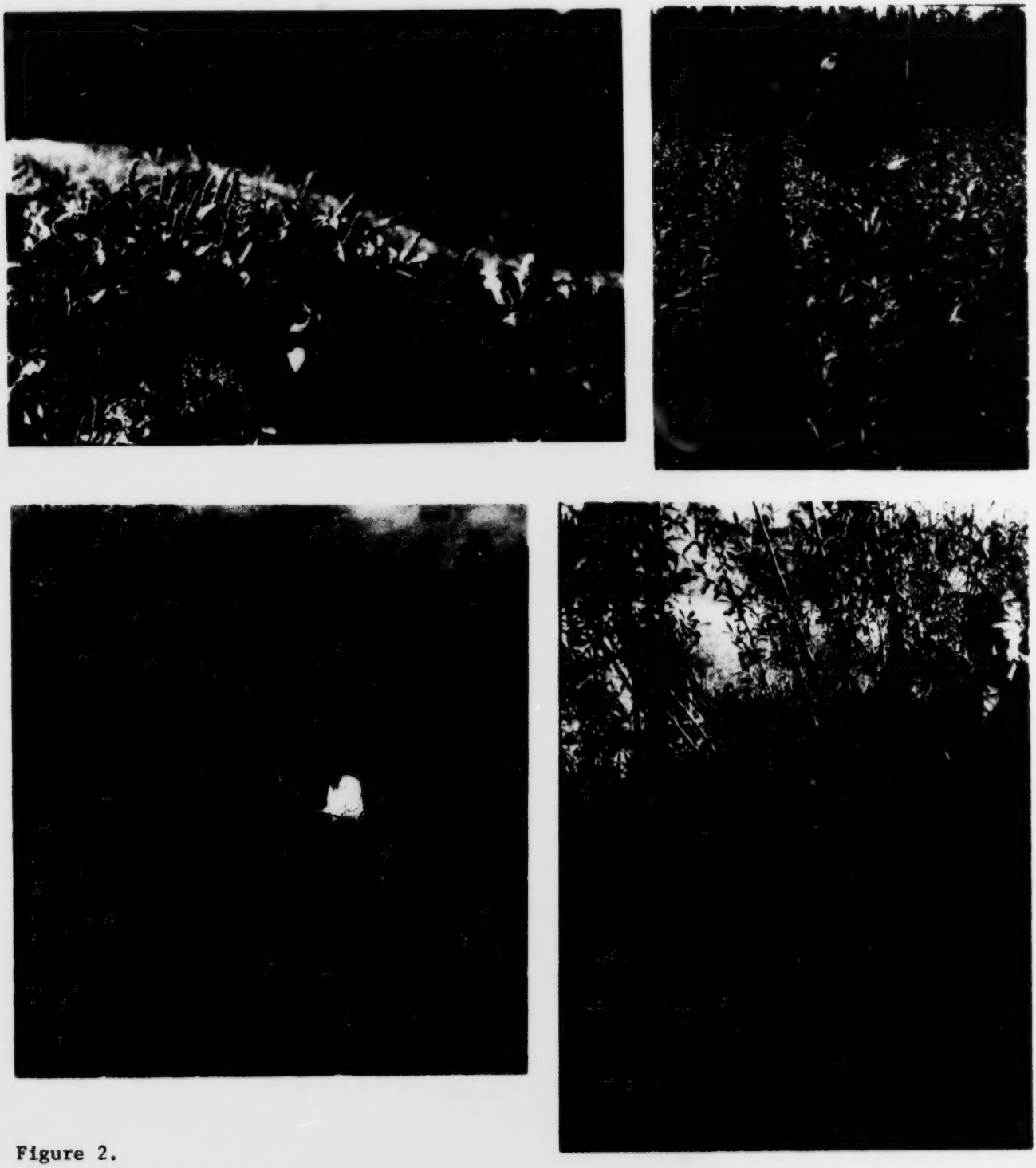


Figure 2.

(Top left) Salix reticulata at Oulu Botanical Garden, Oulu, Finland.

(Top right) Salix triandra, Kannus, Finland.

(Bottom left) Six-month-old (foreground) and 1½-year-old (background) Salix aquatica 'GIGANTEA' at Long Ashton Research Station near Bristol, England.

(Bottom right) One-year-old shoots of Salix daphnoides also at Long Ashton Research Station.

Figure 3. (Top) *Salix fragilis* on the Somerset fens, S.W. England.
(Bottom) *Salix alba* var. *argentea* at Oulu, Finland.

southeast and southwest slopes. In Iceland, S. lanata and S. phylicifolia are the most common species and are widely distributed in peatland and moist loess soils of recent volcanic origin.

Arctic tundra willows include Salix nummularia, S. reptans, S. polaris, S. arctica, S. pulchra and S. myrsinites. Although S. reticulata can be included in this category it is not common in the Arctic. Most of these species occur in the Dryad tundra, sedge bogs and mountain passes in the vicinity of summer snow patches (Tikhomirov 1969). Some are quite specific; for example S. reptans, besides occurring on high mountains, prefers seashore sands and littoral soils. S. pulchra, on the other hand, prefers Yernik-moss tundras and low willow thickets of the subarctic. S. polaris favors cold, sparsely vegetated, northeastern slopes. S. reticulata is restricted to high mountains with rich, moist, gravelly soils and low willow tundras. S. arctica is mostly encountered in the northern part of the tundra belt on polygons, patchy dryads and wet mossy tundras. S. myrsinites is not particularly common in the Arctic where it may occur in sphagnum-sedge bogs (Skvørtsov 1968).

Many of these arctoalpine willows are said to be conspecific; for example, S. phylicifolia is said to be conspecific to S. planifolia, which occurs in Newfoundland. But, the status and distribution of many of these circumpolar species are the subject of much debate. Among the best treatments on circumpolar species are those by Argus (1973), Skvørtsov (1968), Hultén (1971), Tikhomirov (1969) and Chmelar (1977).

Xerophytes

Contrary to popular belief that all willows grow in wet places, there are several species which grow in semi-arid conditions, i.e., they are xerophytes. These include Salix daphnoides, S. acutifolia and S. xerophila. Although they prefer dry sites, they can also tolerate moist sites.

Salix daphnoides is endemic to the Scanians, Caucasians and Alps of Europe. Generally, it occupies dry sandy sites and glacial tills. As an extremely drought resistant and a soil improving species, its most notable use is for stabilizing and upgrading spoil banks, borrow pits and dry roadbanks. Besides its functional qualities the bright, bluish waxy gloom on young branches makes it an especially attractive ornamental.

Salix acutifolia, considered by many to be a subspecies of S. daphnoides, is native to the semi-arid continental regions of eastern Europe and Asia. It grows well on sandy soils, attaining heights of 20 m, and is also widely cultivated.

Salix xerophila is a transcontinental species but only extends into Europe to the mountains of Scandinavia and eastern Europe. Its habitats are variable in forest, steppe and tundra and in the rainshadow of east slopes in mountains of humid temperate regions with Laricio-Betula associations and in relic habitats bearing traces of former steppe (Tikhomirov 1969).

Commercial Species

The lowland and boreal willows in Europe are perhaps best known as ruderals. However this does not necessarily mean, as Kellman (1980) implied, that they are relatively short-lived. The shrub types of willows may indeed have a moderate life cycle, vigorous vegetative propagation and produce an abundance of seed capable of prolonged viability in soil - all the characteristics of pioneer species. But there are also some tree-type willows noted for their vigor and moderate life cycle, and a few species with relatively long life cycles comparable to other broadleaved trees such as oak and beech.

Considering there is an estimated 500 species of willow worldwide, only about a dozen species are cultivated in Europe for industrial purposes. However, it should be noted that of this dozen or so, there are great numbers of cultivars and spontaneous hybrids which probably exceed the number of Salix species. Discussion is limited to the natural distribution of the main commercial species.

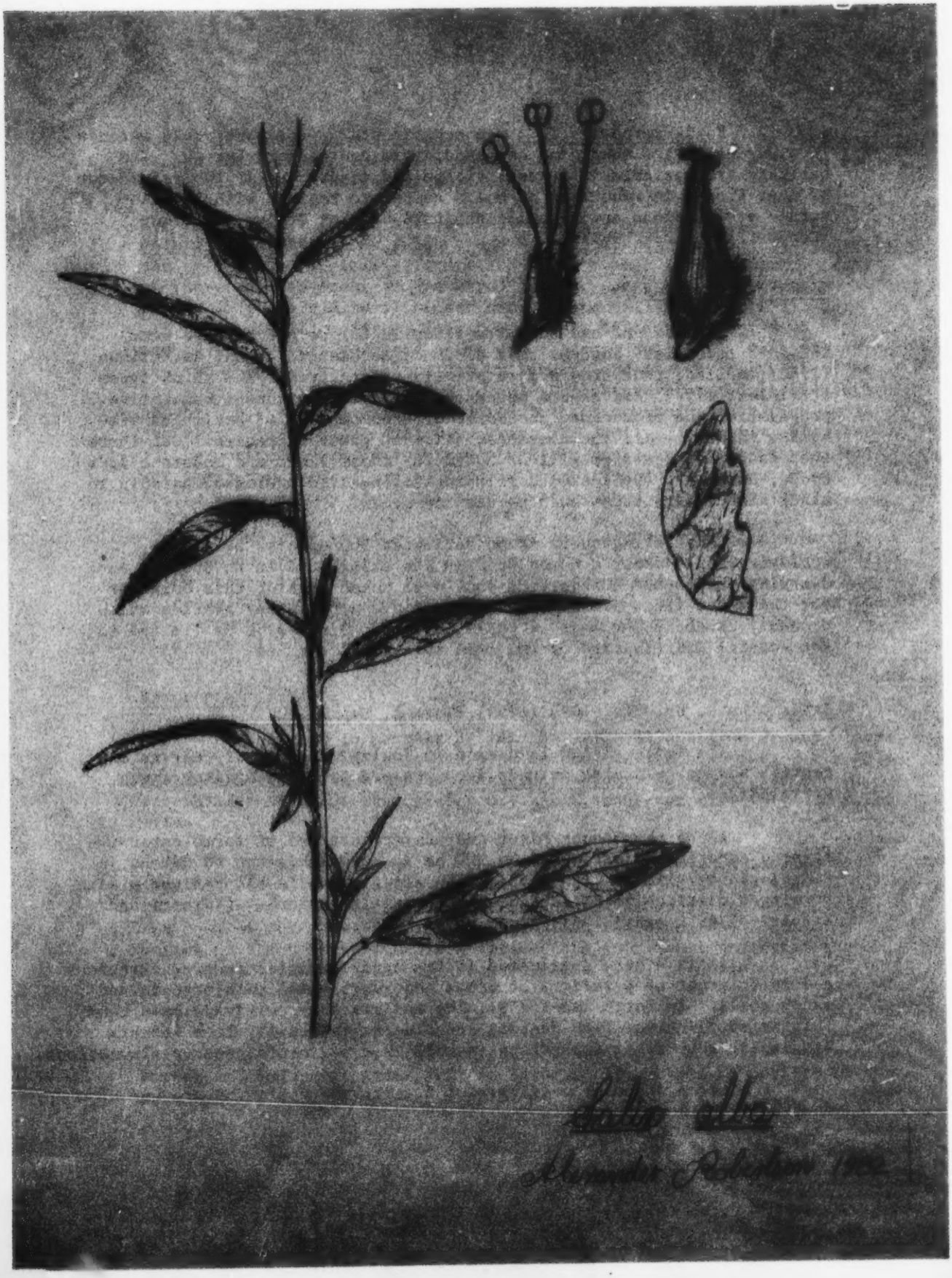
Salix alba L. Sp. Pl., 1021 (1753) Plate 1, Map 1

The white willow is common in lowland regions of western and central Europe. It also extends into western Asia and Mediterranean North Africa.

Along the Danube River and its tributaries it forms extensive stands, covering an estimated 20 000 ha in Yugoslavia and 80 000 ha in Romania (Anon. 1979). It occupies the alluvial soils along flood plains forming a distinctive Salicetum albae-fragilis community (Karpati and Karpati 1974; Karpati 1963; Simon et al. 1980).

It is widely cultivated in temperate and even subarctic regions and is tolerant of a variety of urban and rural sites with organic and sandy soils. In North America S. alba and its many cultivars have been cultivated since the 19th century and clones, especially from Romania and Italy, have grown exceptionally well in experimental energy plantations.

Among the many cultivars of S. alba the following are undoubtedly the most popular.


Salix alba
Alexander Robertson

var. vitellina (L.) Stokes. Golden Willow

This is probably the most common ornamental willow in cultivation. It is easily recognized by its bright yellow or orange-yellow branchlets. Although it has been cultivated since early Roman times for rough baskets and tying vines, it is not known in the wild. This variety actually constitutes a group of clones, with the tree types being generally male, and osier types generally female. This variety is easily distinguished by its compact semi-columnar habit. In fact, one particular clone, cv. 'CRYSOSTELLA' means 'column of gold' and is a male clone of columnar habit noted for its orangy-red tipped shoots.

Some growers erroneously include cv. 'VITELLINA TRISTIS' with var. vitellina. However, this semi-pendulous clone properly belongs under Salix x sepulcralis Simonk, a spontaneous group of hybrids between S. alba and S. babylonica.

f. argentea Wimm. Silver Willow

The silver willow is conspicuous by its silvery-white foliage, easily recognizable from a distance. Its popularity is notable in Finland where it is capable of establishing itself among the native flora. At Oulu, in north-central Finland, for example, it has colonized the banks of rivers and lakes in and around the city where it attains heights of 20 m.

f. caerulea (Sm.) Rech. Cricket Bat Willow

The cricket bat willow is a fast growing tree up to 30 m and 1-1.5 m DBH, with a pyramidal form and erect branches. The leaves are glabrescent above and bluish green beneath; hence it is also known as the 'BLUE WILLOW'. Only female clones are known. Of all the willows, the cricket bat willow is best known for timber which had many uses such as trusses and rafters for building construction, turnery, tool handles, cooperage, etc. The bark had a quality almost equal to oak for tanning (Loudon 1844). As a fuelwood tree it is particularly suitable for mini-rotation forestry (5-10 years) since it puts on girth rather quickly. Since it also provides an excellent screen quickly the shelterbelt option can also be combined with production of fuelwood if space allows for several rows of trees.

cv. 'CARDINAL'. Cardinal Willow

This is a female clone with carmine red first-year shoots. A male clone, known as cv. 'BRITZENSIS' also has carmine red shoots. As a tree both clones have a compact narrow habit. To highlight the bright red shoots in winter for ornamental purposes they are usually cut back each spring.

Salix babylonica L. Sp. Pl. 1017 (1753)

Although not native to Europe a discussion of cultivated willows would not be appropriate without mention of the 'WEEPING WILLOW'.

S. babylonica is known only in cultivation and is believed to have originated in northern China and brought to Babylonia via the ancient trade route through southeast Asia. The nearest relative to S. babylonica is the 'PEKING WILLOW' (S. matsudana Koidz.), although Skvørtsov (1968) considers the latter to be related to the former. Apart from some apparent differences in the structure of the female flower, S. matsudana, unlike S. babylonica, has a native distribution, i.e. in semi-arid regions of northern China. Furthermore, the CORKSCREW or DRAGON'S CLAW WILLOW (S. matsudana var. tortuosa) is a well known variety which bears no resemblance to S. babylonica.

Clones of S. babylonica are almost exclusively female. Skvørtsov (1968) describes several clones, one of them a male, cultivated at Tradjistan, on the ancient trade route to Babylonia. In the Himalayas along the Indo-Tibetan border male trees are most frequently encountered and are considered to belong to a single clone (Bean 1980).

The weeping willow needs no introduction to most people. It is a medium-sized tree 15-20 m tall, low-branching from trunk with a broad, pendulous habit; the trunk is greyish-brown and young branches yellowish-green.

Salix caprea L. Sp. Pl. 1020 (1753)

The 'GREAT SALLOW' or 'GOAT WILLOW' is native to Europe and Asia and is notable for its vigorous growth in poor soils. It is a very bushy shrub or small tree and is propagated freely from seeds. Some clones, however, are not so easily propagated from cuttings as most other willows are. Like the 'COMMON SALLOW' (see S. cinerea below), the great sallow is ideal for coppicing on marginal sites, particularly in boreal regions. These two species readily interbreed and hybrids are represented by S. x reichhardtii A. Kern. The hybrids are fertile and backcrossing results in considerable variations which are often difficult to distinguish from the parent species. In such cases a useful diagnostic feature is to check for striae (longitudinal ridges) under the bark of second-year wood. It is present in S. cinerea but absent in S. caprea.

In natural vegetation S. caprea is a constituent of the Agrostis-Frangula and Molinia-Frangula subalpine communities (Passarge 1973).

Salix cinerea L. Sp. Pl., 1021 (1753) Common Sallow

The common sallow is a temperate-boreal species of Europe and western Asia. Within its range it has a rather sporadic distribution occupying only fens. It is represented in Spain and the British Isles by the fen sallow S. atrocinerea which tolerates drier sites on banks of ponds and streams.

Salix caprea

Alexander Robertson 1982

Salix cinerea

Alexander Robertson 1982

Both species generally prefer calcareous fens in valleys and seepage slopes characteristic of Schoeno-Juncetum subnodulosum associations (Wheeler 1980a). S. cinerea also occurs in Osmundo-Alenetum glutinosa forested fens (Wheeler 1980b). Both these vegetation communities are well represented throughout lowland temperate Europe (Bellamy 1967). Wheeler (1980b) also described a Salicion cinerea alliance within an immature, open acidophilous Betulo-Dryopteridetum cristatae association including S. aurita, S. repens, S. cinerea among the Frangula alnus and Alnus glutinosa shrub layer.

A vegetation type common in Scandinavia and the Baltic countries is the Crepido-Salicetum pentandrae association containing such characteristic species as S. pentandra, S. cinerea along with Crepis paludosa, Geum rivale and Carex rostrata (Bellamy 1967). In this association S. pentandra and S. cinerea reach heights of 5-8 m, with S. repens and S. phylicifolia in the shrub layer.

Salix daphnoides Vill. Hist. Pl. Dauphin. 3:765 et tab. 50 Fig. 7

Native of Europe, the 'VIOLET WILLOW' is noted for the blueberry colored bloom on its shoots, and brittle twigs. It is a medium-sized tree up to 12 m but when cut back hard each spring the vigorous wands have an attractive winter effect which are known in the basket trade as 'violets' or 'French purples'.

As noted earlier S. acutifolia is generally considered a subspecies of S. daphnoides and is distinguished by its narrower leaves and often arching shoots. More pendulous forms are represented by two male clones cv. 'PENDULIFOLIA' and cv. 'BLUE STREAK', neither of which are cultivated as often as they should be.

Salix fragilis L. Sp. Pl., 1017 (1753)

The distribution and ecology is similar to Salix alba except that it does not occur eastward of 60° longitude (Skvørtsov 1968, Jalas and Suominen 1978). It prefers mesotrophic soils but avoids calcareous sites (Wasielewski 1982).

The 'CRACK WILLOW' gets its name from the ease with which twigs can be snapped off at the joints with an audible crack. Another feature is that watershoots are reddish, as is the timber. The timber is tough and durable and withstands considerable friction which made it very useful for moving parts in water-powered mills, wheels and carts since long before Theophrastus.

It has also been one of the dominant species in basket work and over the centuries many hybrids have arisen or, since the Renaissance, been bred to produce superior clones; although, in most cases before the advent of controlled pollination, the parentage involving S. fragilis is

Salix fragilis
Alexander Robertson 1982

often presumed. For example, two well known taxa, S. x rubens Schrank and S. x decipiens Hoffm. are generally considered to be hybrids between S. fragilis and S. alba; but other combinations with or without S. fragilis in the parentage, have often been proposed. In any case, the importance of S. fragilis in breeding programs has resulted in many commercially successful clones.

Salix pentandra L. Sp. Pl., 1016 (1753)

The bay willow has an ecology and distribution similar in many respects to S. cinerea, except that it has a broader ecological amplitude.

In Poland one of the most common shrub associations on peatlands is the Salicetum Pentandra-Cinerea association which is differentiated into a number of variants (Robertson 1980). The dominant species in this association is S. pentandra, S. cinerea, S. aurita and Frangula alnus.

Braun-Blanquet (1973) described a Salix daphnoides sub-variant in a primary association of well-developed substrate in alpine ravines of siliceous mountains, which included S. pentandra, S. eleagnos, S. purpurea and S. phylicifolia besides S. daphnoides. A number of willows are also present in an Astragaletosum sempervirentis sub-association, including S. pentandra, S. albicans, S. appendiculata, S. foetida, S. hastata and S. phylicifolia.

The bay willow is one of the most widely cultivated willows and is particularly hardy and suitable for acid soils in northern climates.

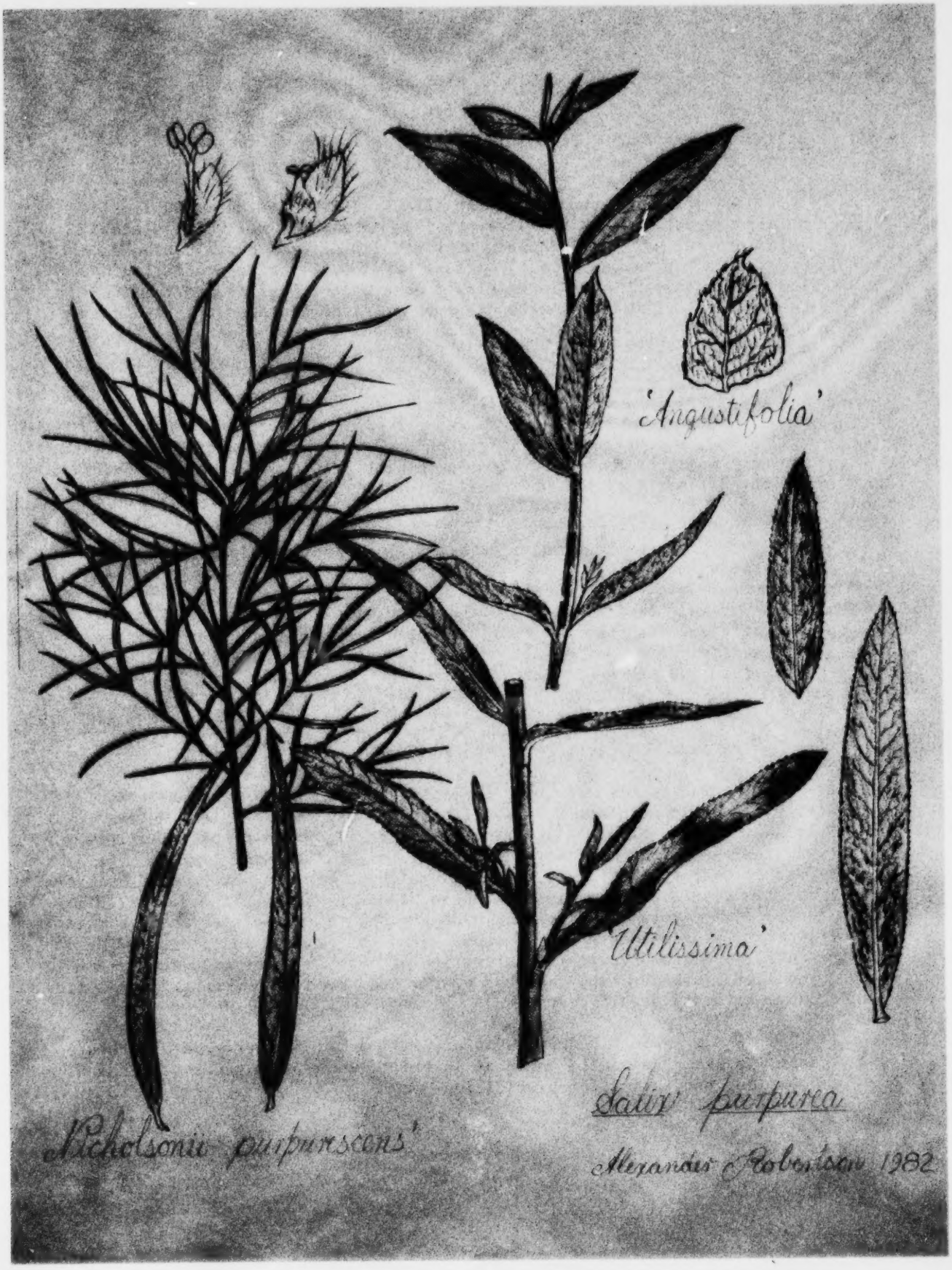
Salix purpurea L. Sp. Pl., 1017 (1753)

The purple osier is endemic to Europe (except Scandinavia) and Mediterranean North Africa. It is more or less a sub-continental-temperate willow, preferring mesotrophic fens and edges of lakes characteristic of rapidly silted areas.

Cultivation of the purple osier for basketry and tying vines in Europe is also of great antiquity. Elsewhere, it is one of the most valuable ornamental species. Its many dwarf forms are often referred to as 'Arctic' willow giving the incorrect impression that it occurs naturally in the Arctic.

Numerous hybrids and cultivars have been produced, mostly for the ornamental trade.

Salix pentandra
Alexander Robertson


'Angustifolia'
'Utilissima'
Salix purpurea
Alexander Robertson 1882
'Nicholsonii purpurascens'

Salix triandra L. Sp. Pl., 1017 (1753)
(syn. S. amygdalina L. op. cit. 1016 (1753))

Often referred to as the 'BLACK WILLOW' its distribution is mainly temperate Eurasia. However, like so many of the willows that have been cultivated since ancient times its natural distribution is uncertain. It is one of the dominant species for osier production and its many cultivars are distinguished more by the quality and color of the rods rather than any external morphological features. It is particularly suited to wet, peaty soils and is one of the main contenders for energy plantations on peatlands in Scandinavia.

Salix viminalis L. Sp. Pl., 1021 (1753)

The basket willow is distributed throughout most of Europe and northern Asia, being absent from Spain, the British Isles and Scandinavia - although it may very well be considered native to southern Sweden and Finland.

It grows best on moist but well-drained nutrient rich sites (Skvørtsov 1968).

This species is one of the most widely cultivated willows in the world and its fame for basketry dates back to ancient Greek times. As a very vigorous and highly productive osier it is ideally suited for short rotation energy plantations.

THE PROBLEM WITH HYBRIDIZATION

The cultivation of willows since ancient times has created many taxonomic problems. Generally, these taxonomic problems have arisen through polyploidy, i.e. the plasticity of the genus for inter- and intra-specific hybridization by natural and artificial means. Furthermore, the difficulty in distinguishing between natural and hemerophilic distribution of willows in many parts of Europe adds to the confusion. Only in the Arctic tundra and alpine regions can we be reasonably certain of truly virgin vegetation. Elsewhere, in the valleys and plains of a highly populated Europe the definition of natural vegetation ecosystems requires close scrutiny, because everywhere, even by atmospheric pollution, human activity is all-pervasive.

No taxonomic discussion of Salix would be appropriate without acknowledging the perils inherent in the taxonomy of a genus that has a notorious reputation for hybridizing.

Salix triandra
Alexander Robertson 1982

Viminalis'
Salix viminalis
Napoleonensis'

Hybridization, as a biological phenomena, was not well-accepted until the late 18th century. After all it was only in 1694 that Camerarius had established the principle of sexuality in plants. When Linneaus wrote on the sexuality of plants (Staflue 1976) one of his critics chastised him by declaring that:

"God would never permit such promiscuity in the plant world."

Notwithstanding these early disputes the general refusal to recognize natural hybridization led to an excessive number of Salix species that lasted well into the 19th century.

It was Lasch (1857) in east Prussia who perceived that interspecific hybrids in Salix, as well as other genera, were more common than generally conceded. Wimmer (1866) and Andersson (1867) were particularly supportive by recognizing hybrids in their own treatments on the genus Salix. Wichura (1865) and Leefe (1871) showed that Salix hybrids were fertile and could be backcrossed and re-crossed, although some, like Salix x calodendron Wimm., were sterile even when the male plant of a related species is nearby (Nilsson 1954).

It has been known at least since Theophrastus (370-285 BC), that willows seldom reproduce from seeds except as ruderals on bare soil, such as gravel pits, fresh roadbanks and recent lacustrine soils. It is as a ruderal on these sites that the majority of spontaneous hybrids are found. Leefe (1871) observed that reproduction from seed in closed (subseral) communities is rare and that most hybrids found on such sites are hemerophilic.

Of the European willows some hybrids are thought to be single clones in which female plants are unknown. This includes S. x calodendron, as mentioned, whose parentage is uncertain. Wimmer (1866) considered it a hybrid between S. caprea x S. dasyclados; but the status of S. dasyclados is contentious.

Besides the taxonomic problems associated with natural and artificial hybridization, Kerner (1889) alludes to morphological changes of alpine species when cultivated at lower altitudes. Often, species relocated from one extreme environment to another are so dissimilar from the typical natural form that, had we not known their origin, they would doubtless be given a pseudonym either as a species, variety, cultivar or a hybrid. In fact, it is likely that many apophytes which escaped cultivation or accidentally established in new habitats gave rise to a multitude of such putative hybrids.

Apophytes are common in Europe. In their treatment of the hemerophilous flora of Kuusamo District in northern Finland, Ahti and Hämet-Ahti (1976) discussed several apophytic willows, including Salix

phylicifolia, S. myrsinifolia, S. starkeana, S. xerophila, S. aurita, S. cinerea, S. caprea, S. lapponum, and an introgressive hybrid S. starkeana x xerophila. These native species appear in man-made habitats; for the most part in ditches, fields and other disturbed habitats.

One must be careful not to confuse apophytes with hemerochores or anthopochores, i.e. alien species introduced by man and escaped cultivation. In the age-old agricultural regions the distinction between apophytes, endemics and hemerachores may be obliterated in some localities. This has led to problems in defining the natural distribution of many species, such as those discussed by Jalas and Suominen (1978) in Florae Europaea.

Upon examination of clonal material in experimental energy plantations and early botanical texts there appears to be a distinctive nomenclatural trend; namely, that what growers now generally call S. x smithiana was, at the turn of this century, called S. dasyclados and vice-versa.

It appears that the various interspecific hybrid combinations in various clone banks are based on rather loose assumptions. For example, it is not uncommon to find clones labeled as interspecific quadhybrids, i.e. S. aurita x caprea x cinerea x viminalis and S. aurita x caprea x myrsinifolia x viminalis, respectively. On the whole the distinctions between these quadhybrids are quite vague and have close affinity to S. calodendron Wimm. and the cultivar S. AQUATICA GIGANTEA (= S. dasyclados Wimm. of most European authors) which are widely cultivated and found in hedgerows and waste places throughout central and northern Europe.

The general assumption for the interspecific hybrid specimen S. aurita x caprea x myrsinifolia x viminalis is mainly based on the existence of striae under the bark of twigs. The leaves and stipules certainly have the classic S. caprea x viminalis parentage. But in reality the best that could be inferred is to include one parental species with striae.

But this taxonomic conundrum is not as simple as this; in fact, it becomes a complex plot of conjecture and refutation. From a contemporary standpoint there are four taxa involved S. dasyclados, S. x aquatica, S. x smithiana and S. x calodendron. Apart from their antiquity in cultivation they are particularly interesting because of their potential for energy plantations. Therefore, it would be desirable that attempts be made to define their status as distinct taxonomic entities. The above mentioned 'quadhybrids' are relevant to this discussion because they are both closely related to the four taxa just mentioned and, although the foregoing discussion of the four taxa may not satisfactorily resolve the problems, it may result in some nomenclatural uniformity between growers in different parts of Europe.

Salix dasyclados Wimmer Flora 32:35 (1849)

If we accept S. dasyclados as a native species then its natural distribution is primarily Siberian, extending westward to the Baltic (Skvørtsov 1968; Jalas and Suominen 1978). Skvørtsov (1968) accords species rank to S. dasyclados, noting that variations are merely geographic variations mainly on a north-south transect. But, Jalas and Suominen (1976) suggest that Skvørtsov's eastern taxon should not be confused with the true, long-cultivated, hybrid S. x dasyclados which they treated as a synonym of S. burjatica Nasarov. But the fact that Skvørtsov also considered his eastern S. dasyclados as a synonym of S. burjatica suggests he is standing on firmer ground. Furthermore, Jalas and Souminen stated their assumption was made without adequate reasoning.

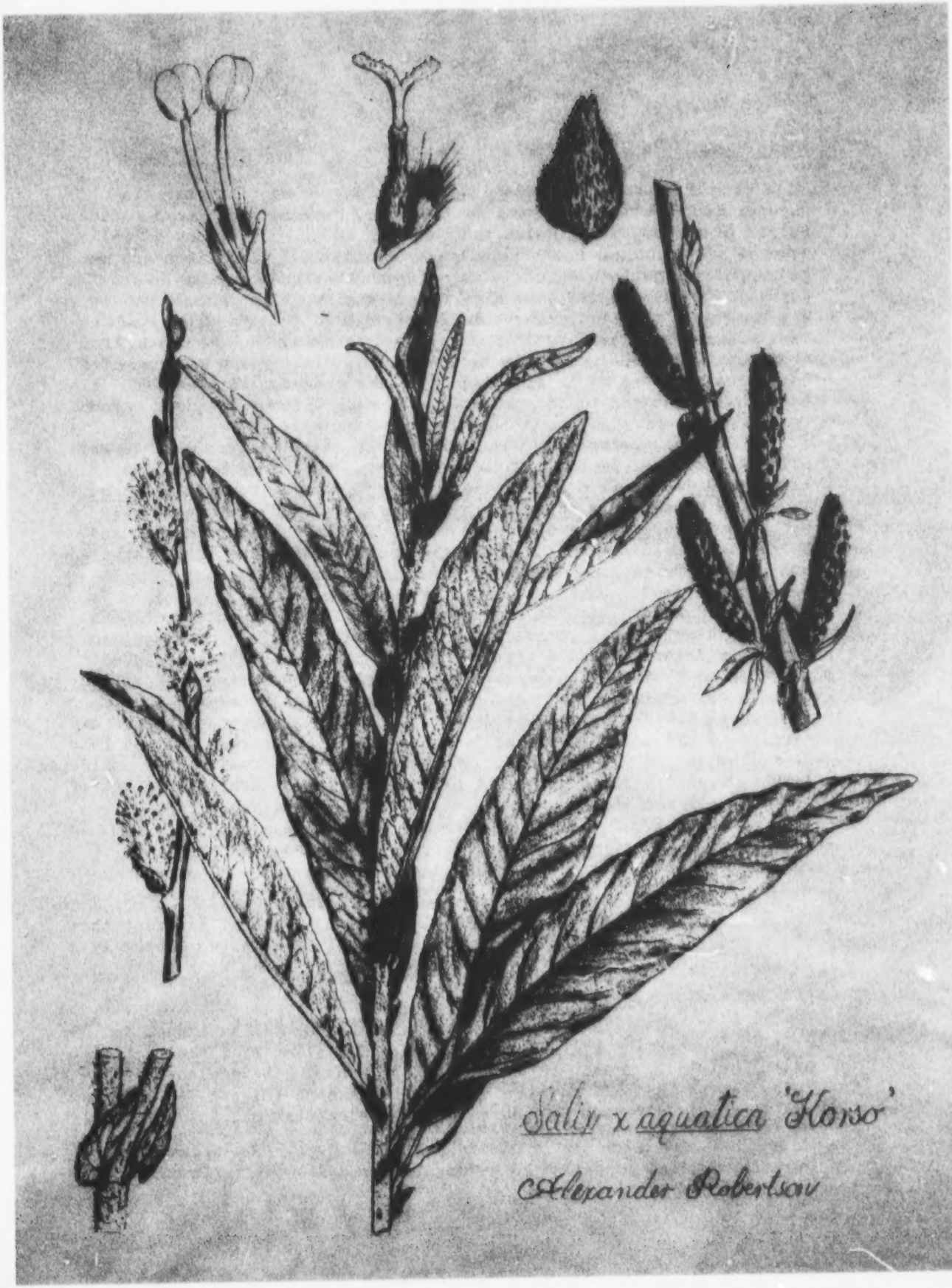
Nevertheless the plasticity of S. dasyclados is well-known. Nilsson (1931) produced a hybrid by crossing two other hybrids, S. x tenuiflora Sm. (= S. myrsinifolia x phylicifolia) with S. x sericans Tausch ex Kerner (= S. caprea x viminalis) resulting in a quadruple hybrid S. x dasycladoides similar to S. dasyclados Wimm. Neuman and Polatschek (1972) have also confirmed the hybrid nature of S. dasyclados non-native plants from Austria.

Håkansson (1955) discussed the cytological aspects of S. x laurina in an attempt to establish its parentage. The parentage was generally regarded as S. cinerea x phylicifolia; but Nilsson (1928) produced an F_2 S. viminalis x caprea which was so similar to S. x laurina that he called it S. x superlaurina. Nilsson (1953) crossed S. x superlaurina with S. x dasycladoides to produce a vigorous, robust and fertile hybrid which he called S. x dasylaurina. Nilsson implied that S. x dasylaurina may also occur in nature, but since no one has collected it Håkansson (1955) described it as an example illustrating his belief of the impossibility of a new species arising in nature.

Salix x aquatica

This putative hybrid has no author simply because no one knows its origin despite its long cultivation. Among growers, particularly those engaged in energy plantation research, there are two extremely vigorous clones, they are S. x aquatica 'GIGANTEA' and S. x aquatica 'KORSO'.

In 1981 the author observed a number of willow clones in England, Sweden and Finland. In Sweden and Finland S. x aquatica of Danish origin is widely cultivated and is easily distinguished by its large leaves that are somewhat velvety underneath (Figure 31). But at the National Salicetum at Long Ashton Research Station, Bristol, England


Salix x aquatica 'Horso'
©Alexander Robertson

S. x calodendron and S. x aquatica are remarkably similar. In the Salicetum at Brno, Czechoslovakia the cultivar 'AQUATICA GIGANTEA' is considered a cultivar of S. dasyclados Wimm. Neither Skvørtsov (1968), Miekle (1975) or Jalas and Suominen (1978) mention S. x aquatica even though it has become synonymous with energy plantations in northern Europe.

Salix x smithiana Willd. Species Plantarum, Salix 653710 (1806)

This taxon is similar in all respects to S. x aquatica, except that the upper surfaces of the leaves are lustrous. Miekle (1975), on the one hand, considers it to be a hybrid between S. cinerea x viminalis, but adds that it is not easily distinguished from S. x sericans (= S. caprea x viminalis) which as was pointed out in the discussion on S. dasyclados is one of the parents of the quadruple hybrid S. x dasycladoides. In fact, Miekle considered S. x laurina Sm. sec. Nilsson, to be a synonym of S. x sericans.

The Salicetum (Index Plantarum), Brno lists S. x smithiana as a hybrid between S. caprea x viminalis, coincidentally the same parentage as S. x sericans. But this combination seems unlikely, because neither parent has striae under its bark; thus Miekle's (1975) combination is more likely. Clapham, et al. (1962), being categorical about S. x smithiana as a hybrid between S. cinerea x viminalis, suggests that S. x stipularis Sm. is either a hybrid of the same parentage or of S. x calodendron x viminalis. However, their comparative descriptions of the two taxa appears superficial; Skvørtsov (1968) states that S. stipularis, S. smithiana (giving them species rank) together with S. acuminata, S. longifolia and S. calodendron are all very similar to S. dasyclados. Presumably he meant they were all sufficiently distinctive enough to be segregated.

S. x smithiana is a common hedgerow plant and is found in thickets and waste ground in central and northern Europe. It is one of the prime candidates for fast growing, highly productive energy plantations.

Salix x calodendron Wimmer Flora 32:36 (1849)

While contemporary growers, and perhaps even taxonomists, might come to a reasonable understanding on the status of S. dasyclados, S. x aquatica and S. x smithiana as distinct nomenclatural entities, the status of S. x calodendron is invariably more complex.

Miekle (1952) considered S. x calodendron to be a hybrid between S. caprea x cinerea x viminalis. Stott (1981) provides a tentative list showing the parentage of S. x dasyclados and S. x calodendron

Salix x smithiana
Alexander Robertson 1982

Salix x calodendron
Alexander Robertson 1982

derived by consultation with Miekle. Clapham et al. (1962) follow Miekle's treatment by giving S. x acuminata and S. x dasyclados as synonyms of S. x calodendron by speculating the same parentage.

Clapham et al. (1962) alludes to S. x stipularis as a hybrid either between S. cinerea x viminalis or S. x calodendron x viminalis. But as noted earlier it is the author's view that S. x calodendron and S. x stipularis are one and the same, albeit the slight superficial differences. In essence, Clapham et al. (1962) implied that S. x stipularis has S. viminalis as a double parent; firstly if one accepts Miekle's (1952) view that S. x calodendron = S. caprea x cinerea x viminalis and, secondly, Clapham et al.'s (1962) view of the parentage of S. x stipularis it would be necessary to choose between a simple combination (i.e., S. x stipularis = S. cinerea x viminalis), or the more complex one (i.e., S. x stipularis = [(S. caprea x cinerea x viminalis) x viminalis]. In either case the true status of either S. x calodendron or S. x stipularis has not been established. Their distinction appears to be more a nomenclatural problem than a taxonomic one, per se.

In practice, S. x calodendron is interchangeable between S. dasyclados, S. x smithiana and S. x aquatilis, depending on which part of Europe it is found. More generally, however, it is treated as a synonym or close relative of S. x aquatilis and S. x smithiana. In the author's view it should not be considered a geographic variant, of Skvortsov's S. dasyclados, but a hybrid of similar parentage as S. x aquatica.

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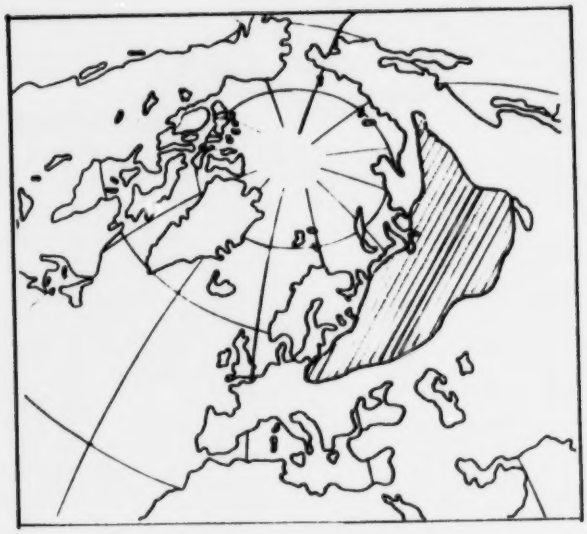
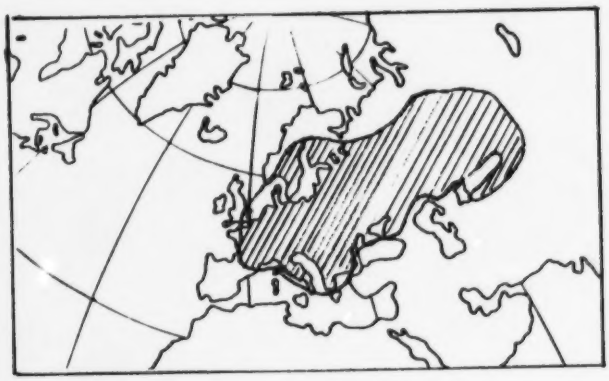
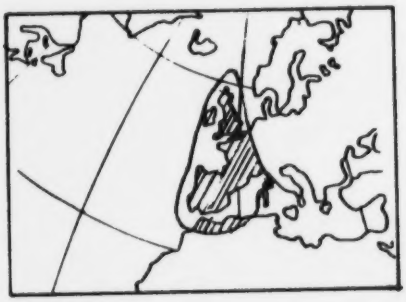


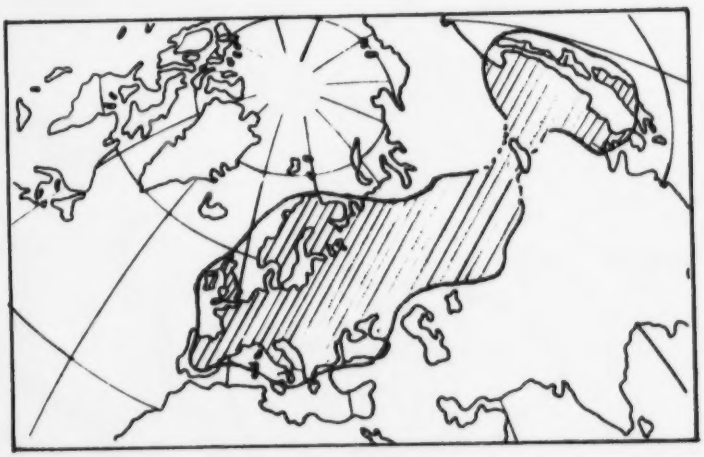
Salix dasyclados Wimm.
Skvortsov (1968), 197
Jalas & Souminen (1978), Map 202



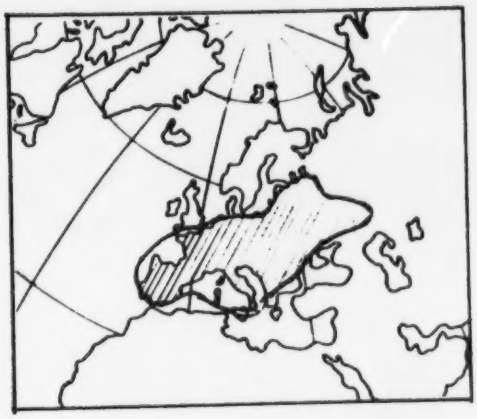
Salix cinerea L.
Skvortsov (1968), 170
Jalas & Souminen (1978), Map 235



Salix atrocinerea Brotero
Skvortsov (1968), 170
Jalas & Souminen (1978), 234

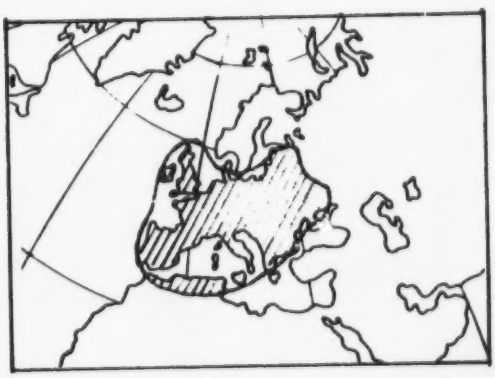


Salix caprea L.
Skvortsov (1968), 85
Jalas & Souminen (1978), 238

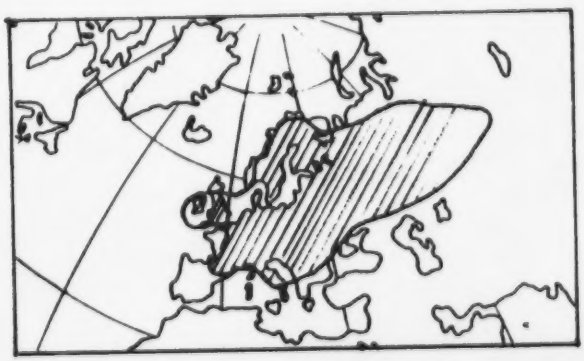


Salix fragilis L.
Skvortsov (1968), 112
Jalas & Souminen (1978), Map 202

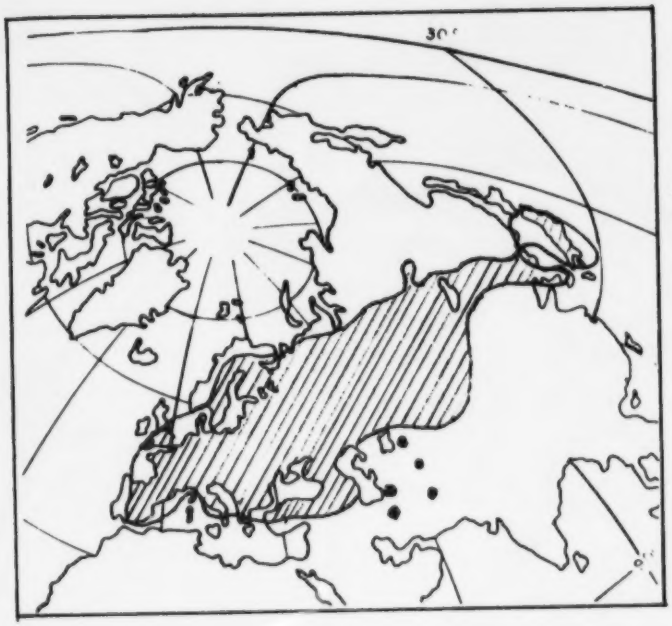
Salix viminalis L.
Skvortsov (1968), 194
Jalas & Souminen (1978), Map 252



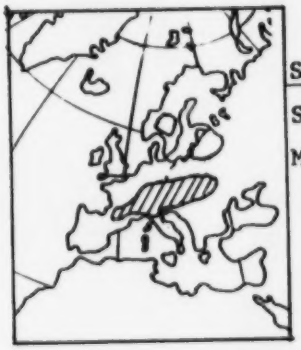
Salix purpurea L.
Skvortsov (1968), 227
Jalas & Souminen (1978), Map 255



Salix pentandra L.
Skvortsov (1968), 106
Jalas & Souminen (1978), Map 201

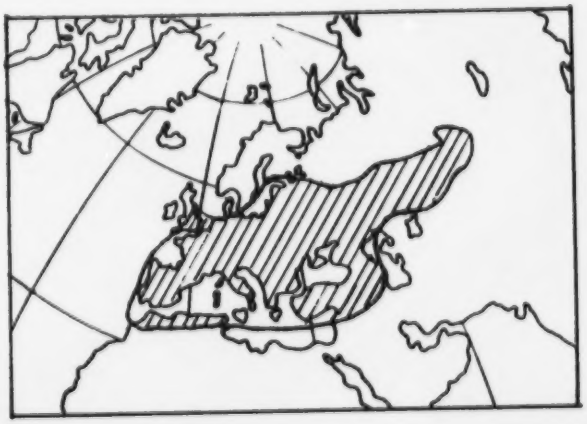


Salix triandra L.
Skvortsov (1968), 102
Jalas & Souminen (1978), Map 204



Salix daphnoides Vill.
Skvortsov (1968), 213
Map 261

Salix acutifolia Willd.
Skvortsov (1968), 213



Salix alba L.
Skvortsov (1968), 110
Jalas & Souminen (1978),
Map 203